# Evaluation of radiopacity of cements used in implant-supported prosthesis by indirect digital radiography: an *in-vitro* study

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***Abstract***

In order to help dentists in choosing the right type of cement for implant-based prostheses, the radiopacity of commonly used cements available in the market was investigated by digital radiography with PSP sensor. In the present study, temporary cements of TempBond (Kerr, Germany), TempBond clear (Kerr, Germany), Dycal (Dentsply, USA) and permanent cements of Multilink N (Ivoclar, Brazil), Panavia F 2.0 (Kurrary, Japan), Fuji plus (GC, Japan), RelyX (3M, USA), Durelon (3M, USA) were used. Four pill-like samples with 0.5 mm and 1 mm thickness and 5 mm in diameter inside the silicon index as recommended by the manufacturer were prepared for each cement. Aluminum step wedge (99% aluminum alloy) was used as control. Using digital radiography, cement and aluminum step wedge samples were radiographed. The images of cement tablets were measured by digital radiography using DFW software to check their radiopacity values. Bonferroni test and Mann-Whitney U test were used for comparison of cements. The highest radiopacity between the group of 1 and 0.5 mm thickness was related to Glass ionomer Fujiplus GC (2407±45..99) and TempBond (137.21±22.46) cement, respectively. Whereas, the lowest radiopacity among the groups was related to Clear cement. The difference between the mean radiopacities among the studied groups was statistically significant ($p<0.001$). Based on the results, among the available cements, Glass ionomer Fujiplus GC and TempBond cement are the most efficient for 1 and 0.5 mm thickness, respectively, and Clear cement is the least efficient cement in both groups in terms of radiopacity.

**Key Words**: radiopacity; cements; radiography; aluminum.

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**D**ental implant is successful treatment option for replacing missing teeth which can be either screw or cement retained.[1] Excess cement extrusion is one of the most common problems of cemented prostheses.[2] When the crown margin is placed deep in the peri-implant sulcus, there is a high probability that excess cement will remain in the sulcus, especially when the margins are 1.5 to 3 millimeters below the gingiva.[3] The soft tissue located above the crestal surface of the implant does not usually act as a mechanical barrier; therefore, it does not prevent excess cement from being directed apically into the peri-implant sulcus. Unlike natural teeth, implants are more vulnerable to irritants under the gingiva such as cement, since the fibers of the gingival connective tissue are not perpendicular to the implant, but are located near the surface of the implant and almost parallel to them. Subgingival excess cement can cause peri-implant inflammation associated with swelling, increased probing depths, bleeding, pus discharge and radiographic evidence of bone loss.[4] This peri-implant inflammation caused by cement may lead to the failure of the implant treatment.[5] Removal of excess cement by visual and tactile methods is problematic, even when supragingival margins of the crown and abutment have been placed.[3] There are several techniques in order to determine the residual cement around the implant such as the use of a dental endoscope or a more invasive method like open flap debridement, which allows direct observation of the cement.[2] A non-invasive technique to evaluate the presence of excess cement is the use of periapical radiography in a parallel way.[5] Using a variety of digital images and image analysis programs allows studying the radiopacity of cements to be easy, repeatable and reliable.[1] In the meantime, it is essential that the cement be as radiopaque as possible. As the radiopacity of luting agent is important in the diagnosis of secondary caries, and it should be more than the radiopacity of dentin, so it is vital that the luting agent be more radiopaque than titanium or other metals used.[2] Several factors may affect

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***Table 1.*** *Radiopacity of studied cements in thicknesses of 1 and 0.5 mm.*

| Cement | Mean and Std. deviation (1 mm thickness)[a] | Mean and Std. deviation (0.5 mm thickness)[b] |
|---|---|---|
| Panavia F2.0 | 205.22±16.30 | 116.22±9.15 |
| TempBond | 231.40±8.71 | 137.22±21.46 |
| Glass ionomer Fujiplus GC | 240.45±7.99 | 126.70±12.46 |
| Dur elon | 232.60±7.12 | 129.87±12.45 |
| RelyX | 230.80±9.23 | 123.20±10.46 |
| Multilink | 211.20±8.58 | 129.80±9.17 |
| Clear | 121.80±30.70 | 46.10±9.68 |
| DyCal | 225.30±11.60 | 119.50±8.90 |

the radiopacity of cements. The composition of the cement has the highest importance. In addition, exposure factors, the angle of radiation and the radiographic technique used also have a proven role.[5] The sensor used in this study is PSP, which includes a phosphor layer on the plate, forming a latent image after X-ray exposure. The latent image is converted into a digital image by a laser light scanner. In order to help dentists in choosing the right type of cement for implant-based prostheses, the radiopacity of commonly used cements available in the market was investigated by digital radiography with PSP sensor.

## Materials and Methods

This study was approved by the ethics committee of Golestan University of Medical Sciences, in the ethic No. IR.GOUMS.REC.1394.170. In the present study, temporary cements of TempBond (Kerr, Germany), TempBond clear (Kerr, Germany), Dycal (Dentsply, USA) and permanent cements of Multilink N (Ivoclar, Brazil), Panavia F 2.0 (Kurrary, Japan), Fuji plus (GC, Japan), RelyX (3M, USA), Durelon (3M, USA) were used. 4 pill-like samples with 0.5 mm and 1 mm thickness and 5 mm in diameter inside the silicon index as recommended by the manufacturer were prepared for each cement. Hardening agents went through their setting time suggested by the manufacturer and became hardened. Furthermore, cements were hardened by using light-cure for forty seconds. The samples were then separated and samples containing bubbles were removed and replaced.

Aluminum stepwedge (99% aluminum alloy) was used as control. Using digital radiography, cement and aluminumstep wedge samples were radiographed. The distance of the sensor to the X-ray was considered 30 cm, the radiation conditions were 60 KVP, 10mA, and the time of radiation was 0.3 second. Then the sensors were read by PSP Digora optima device (Soredex, Finland), processed by DFW 2.5 software and saved in the corresponding file.

The images of cement tablets were measured by digital radiography using DFW software to check their radiopacity values. The obtained values were analyzed using IBM SPSS V.18 software. Due to the normality of the data values obtained from aluminum stepwedge and 1 mm thick cement, the comparisons were done by using ANOVA and Bonferroni test. On the other hand, due to the lack of normality assumptions for 0.5 mm thick cement, the Mann-Whitney U test was used for one-by-one comparisons The limit for statistical significance was always considered $p<0.05$.

***Table 2.*** *Radiopacity of aluminum stepwedges.*

| Aluminum stepwedges | Mean and Std. deviation |
|---|---|
| Step 1 | 55.5±80.26 |
| Step 2 | 133.6±60.50 |
| Step 3 | 187.±77.02 |
| Step 4 | 217.460±.37 |
| Step 5 | 236.2±10.13 |
| Step 6 | 247.1±50.26 |
| Step 7 | 254.2±98.71 |

## Results

The highest radiopacity between the groups in 1mm thickness was related to Glass ionomer Fujiplus GC cement with mean and standard deviation of 240.45±7.99 (pixels). Whereas, the lowest radiopacity among all groups was related to Clear cement with mean and standard deviation of 121.80 ± 30.7 (pixels). Also, the difference between the mean radiopacities among the

***Table 3.*** *Comparison of the cements' mean difference (1mm thickness).*

| Cement | | Compared with | Mean difference | P-Value |
|---|---|---|---|---|
| TempBond | | Multilink | 20.20 | < 0.001 |
| | | Rely X | 0.52 | 1 |
| | | PanaviaF2.0 | 26.17 | < 0.001 |
| | | GC Fujiplus | -9.05 | 0.002 |
| | | Clear | 109.55 | < 0.001 |
| | | Durelon | -1.2 | 1 |
| | | Dycal | 6.07 | 0.823 |
| Multilink | | TempBond | -20.20 | < 0.001 |
| | | Rely X | -19.67 | < 0.001 |
| | | PanaviaF2.0 | 5.97 | 0.998 |
| | | GC Fujiplus | -29.25 | < 0.001 |
| | | Clear | 89.35 | < 0.001 |
| | | Durelon | -21.4 | < 0.001 |
| | | Dycal | -14.12 | < 0.001 |
| Rely X | | TempBond | -0.525 | 1 |
| | | Multilink | 19.67 | < 0.001 |
| | | PanaviaF2.0 | 25.65 | < 0.001 |
| | | GC Fujiplus | -9.57 | 0.001 |
| | | Clear | 109.02 | < 0.001 |
| | | Durelon | -1.72 | 1 |
| | | Dycal | 5.55 | < 0.001 |
| PanaviaF2.0 | | TempBond | -26.17 | < 0.001 |
| | | Multilink | -5.97 | 0.998 |
| | | Rely X | -25.65 | < 0.001 |
| | | GC Fujiplus | -35.22 | < 0.001 |
| | | Clear | 83.37 | < 0.001 |
| | | Durelon | -27.37 | < 0.001 |
| | | Dycal | -20.1 | < 0.001 |
| GC Fujiplus | | TempBond | 9.05 | 0.002 |
| | | Multilink | 29.25 | < 0.001 |
| | | Rely X | 9.57 | < 0.001 |
| | | PanaviaF2.0 | 35.22 | < 0.001 |
| | | Clear | 118.6 | < 0.001 |
| | | Durelon | 7.85 | 0.004 |
| | | Dycal | 15.125 | < 0.001 |
| Clear | | TempBond | -109.55 | < 0.001 |
| | | Multilink | -89.35 | < 0.001 |
| | | Rely X | -109.02 | < 0.001 |
| | | PanaviaF2.0 | -83.37 | < 0.001 |
| | | GC Fujiplus | -118.6 | < 0.001 |
| | | Durelon | -110.75 | < 0.001 |
| | | Dycal | -103.47 | < 0.001 |
| Durelon | | TempBond | 1.20 | 1 |
| | | Multilink | 21.4 | < 0.001 |
| | | Rely X | 1.72 | 1 |
| | | PanaviaF2.0 | 27.37 | < 0.001 |
| | | GC Fujiplus | -7.85 | 0.004 |
| | | Clear | 110.75 | < 0.001 |
| | | Dycal | 7.27 | 0.234 |
| Dycal | | TempBond | -6.07 | 0.831 |
| | | Multilink | 14.12 | <0/001 |
| | | Rely X | -5.5 | 0.966 |
| | | PanaviaF2.0 | 20.1 | < 0.001 |
| | | GC Fujiplus | -15.12 | < 0.001 |
| | | Clear | 103.47 | < 0.001 |
| | | Durelon | -7.27 | 0.234 |

studied groups was statistically significant using the Kruskal-Wallis test ($p<0.001$). The examination of cements in the thickness of 0.5 mm also demonstrated that the opacity of TempBond cement was the highest with a mean and standard deviation of 137.22±21.46 and Clear cement was the lowest with a mean and standard deviation of 46.1±9.68 as well (Table 1).

Table 2 shows mean and standard deviation of Aluminum stepwedges radiopacities.

***Table 4.*** *Comparing the mean radiopacity ranks of 0.5 mm thickness cements with each other.*

| | Dycal | TempBond | multilink | Rely X | PanaviaF2.0 | GC Fujiplus | Clear | Durelun |
|---|---|---|---|---|---|---|---|---|
| Dycal | * | *** | *** | *** | *** | *** | *** | *** |
| TempBond | <0/001 | * | *** | *** | *** | *** | *** | *** |
| multilink | <0/001 | 0/010 | * | *** | *** | *** | *** | *** |
| Rely X | 0/153 | <0/001 | 0/005 | * | *** | *** | *** | *** |
| PanaviaF2.0 | 0/102 | <0/001 | <0/001 | 0/003 | * | *** | *** | *** |
| GC Fujiplus | 0/011 | 0/007 | 0/048 | 0/305 | <0/001 | * | *** | *** |
| Clear | <0/001 | <0/001 | <0/001 | <0/001 | <0/001 | <0/001 | * | *** |
| Durelun | <0/001 | 0/020 | 0/893 | 0/022 | <0/001 | 0/154 | <0/001 | * |

The mean radiopacity of cements was compared with each other using Bonferroni test in 1mm (Table 3). In comparison of each group with another group in all studied groups for 1mm thickness, the mean diversity between Clear cement with other cements was significant ($p < 0.001$).
The comparison of the mean radiopacity ranks of 0.5 mm thickness cements was done one by one using the Mann-withney test (Table 4). The results showed that there was no significant difference between Rely X cement and Dycal and GC Fujiplus cement. Also, there were no significant differences in PanaviaF2.0 and Dycal cements, Durelun cements with multilink and GC Fujiplus, but there were significant differences in other one-by-one group comparisons.

## Discussion

It is obvious that the residual cement under the gingiva and around the implant causes inflammation in those areas and thus leads to Peri-implantitis and mucositis.[1] Numerous studies have also stated that the tissue around the implant shows a more severe reaction to the residual cement than the tissue around the natural tooth.[6-8] One of the final tasks in the implant prosthesis delivery session is to remove the excess cement around it. The residual cement is checked both clinically and radiographically. Radiopacity is an essential property for cements. In addition to other physical and chemical properties, an ideal cement must have a suitable degree of radiopacity to be seen clearly and transparently in radiography. According to ISO 4049:2000(E), the acceptable radiopacity for luting materials and cements should be equal to or greater than the radiopacity of aluminum.[9-11] The use of radiolucent cements can lead to misdiagnosis of overhangs and failure to detect recurrent caries.[12] The use of these materials is contraindicated in situations such as margins that are difficult to access in cases of recurrent caries.[13] Besides, these radiolucent materials should be used carefully in cases of subgingival restorations since they cannot be seen on radiographs, and can cause periodontal issues.[14-15] On the other hand, the use of materials with high radiopacity can also be problematic. The detection of Void and Gap in the margins is jeopardized in cases of using materials with high radiopacity. In addition, the diagnosis of recurrent caries may be difficult.[15] The radiopaque resin cement use is also important when applying radiolucent restorations such as ceramic veneer laminates, fiber post ceramic inlays and onlays, or restorations with subgingival margins and implants,[16-18] because incomplete cleaning of excess cement in the subgingival areas may accompany periodontal problems around implants and restorations. In fact, when the thickness of cement is less than 25-50 nm after cementing, it is desirable to use cement with high radiopacity in order to ease the radiographic detection.[2,12]
The results of the present research showed that all the studied groups have the necessary standard for radiopacity. The highest degree of radiopacity in 1 mm cement group was related to glass ionomer resin-reinforced GC Fuji plus cement, followed by Durelon cement. On the other hand, the highest degree of radiopacity in 0.5 mm cement group was related to TempBond cement, followed by Durelon cement. The lowest amount of radiopacity belonged to Clear cement in both group. In addition, the difference between the average radiopacity values of cements was statistically significant. It seems that the difference in the composition of the ingredients is the main reason for the difference in the radiopacity of cements. In the present study, Durelon cement (zinc polycarboxylate-based cement) had a high degree of radiopacity. Wadhwani et al.'s study showed that cements containing zinc have higher radiopacity values.[2] Pekkan Gurel et al. stated that radiopacity related to Durelon was higher than the rest.[14] In a separate study, Attar et al. also stated that zinc polycarboxylate has the highest radiopacity value among others.[13] In addition, in a study by Fonseca et al., zinc polycarboxylate cement showed the highest degree of radiopacity.[19] Furthermore, the present study is in agreement with the results Alhavaz et al.[1] and Pette et al.[20]
The X-ray energy absorption of different materials is strongly related to the atomic number of their constituent elements.[21] The absorption of radiation in elements such as barium and silver per unit volume is 10 times higher than that of elements such as carbon and oxygen.[22] Therefore, dental materials containing large amounts of heavy elements are expected to be more radiopaque. High amounts of zinc oxide are observed in the

composition of zinc polycarboxylate cements. Zinc with a high atomic number shows a higher radiopacity than materials such as aluminum and silicon with an atomic number of 13 and 14, respectively.[14]

The results of our study showed that Fujiplus GC (resin-reinforced glass ionomer cement) also has high radiopacity values. The study of Pette et al.[20] also reported the same results. Conventional glass ionomer cements contain aluminosilicate in their composition, and these minerals cause a decrease in the radiopacity of the cement due to their low atomic number.[1] In the study of Pekkan Gurel et al. glass ionomer cement showed a low degree of radiopacity.[14] Besides, Hara et al. stated that conventional glass ionomer cement has low radiopacity.[23] In addition, Alhavaz et al. observed that the lowest radiopacity value was related to conventional glass ionomer cement and even Iranian glass ionomer cement does not have the required standard.[20] Considering the low radiopacity of conventional glass ionomer cements, it seems that this defect has been eliminated in reinforced glass ionomer cements. Adding chemical elements such as Zinc, Strontium, Barium, Lanthanum, Zirconium, Magnesium, Yttrium and Ytterbium to cement can increase the radiopacity of these materials.[23-25] The lowest radiopacity value in the present study was related to Clear Kerr resin cement. In Alhavaz et al.'s study, Choice 2 resin cement showed low radiopacity.[20] In addition, Pekkan et al.'s study stated that resin cements have less radiopacity compared with other cements. Furthermore, Pette et al mentioned that resin cements showed little radiopacity and even some of them did not have the minimum required standard for radiopacity.[1] These findings are similar to the results of the present study. In resin cements, radiopacity depends on the type of polymeric matrix, the nature of the constituent elements of fillers, the size and density of filler, as well as the amount of filler in the matrix. The variation in measured radiopacity of the same material in different studies depends on numerous factors, including the speed of the x-ray film, irradiation time, the voltage used, and the duration of use of the developer and fixer solution.[26] In addition, the distance of the image to the source and the intensifier plates and the thickness of the samples are among the effective factors in the radiopacity of the materials.[27] The aluminum step wedge has been chosen as the gold standard for measuring the radiopacity, since it allows a specialized comparison of the samples thickness in radiographic conditions.[28] Hence in the present study, aluminum stepwedge was used for radiography along with cement samples.

In the present study, PSP digital radiography was used, so that the aluminum stepwedge was placed next to the cement samples and radiographs were taken. Radiographic density was obtained directly from digital image analysis by software. Digital radiography was also used in previously discussed studies.[15,20,28-30] Speeding up the image preparation, the elimination of chemical fixing and developing, as well as the high sensitivity of the film to radiation, along with its acceptability and ease of use, can be mentioned among the advantages of direct digital analysis.[30]

In conclusion, according to the results, in the group of 1 mm thickness Glass ionomer Fujiplus GC, Durelon, TempBond , RelyX, DyCal, Multilink, Panavia F2.0 and Clear cement were fond the highest efficient cement in terms of radiopacity, respectively. In the group of 0.5 mm thickness TempBond, Durelon, Multilink, Glass ionomer Fujiplus GC, RelyX, DyCal, Panavia F2.0 and Clear cement were fond the highest efficient cement in terms of radiopacity, respectively.

## List of acronyms

DFW - Application SoftWare (Digora for Windows)
GC - Glass-ionomer Cement

## Contributions of Authors

Mahla Esfahanian and Amin Mahdavi Asl contributed equally to the typescript. The authors read and approved the final edited manuscript.

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## Conflict of Interest

The authors declare they have no financial, personal, or other conflicts of interest.

## Ethical Publication Statement

We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

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